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Intersection Control through Video Image Processing

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7. Author(s)
Panos Michalopoulos, Ph.D.

8. Performing Organization Rept. No.
9RD0004('90) 9RD0008('91)

9. Performing Organization Name and Address
University of Minnesota
Department of Civil and Mineral Engineering
122 Civil and Mineral Engineering Building
500 Pillsbury Drive, S.E.
Minneapolis, MN 55455-0220

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Among the most promising and innovative concepts today for alleviating urban traffic congestion is the use of video imaging for vehicle detection, automatic surveillance, and advanced control strategies. Because of its conceptual appeal, research in this area was initiated in the mid 70's in the United States and abroad.

A system for vehicle detection through video imaging was recently developed at the University of Minnesota and is being implemented on the I-394 and I-35W freeways in Minneapolis, Minnesota for incident detection. The Minnesota system, called AUTOSCOPE (TM), emulates loop detectors, a large number of which can easily be placed within the field of the camera's view through interactive graphics. In recent tests its performance matched or exceeded that of loops in vehicle counting, speed measurements, and extraction of certain measures of effectiveness.

Evaluation tests of the AUTOSCOPE (TM) were very encouraging, thus the system was installed at a traffic intersection to demonstrate the effectiveness of this new technology as a replacement for loop detectors.

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Intersection Control Through Video Image Processing

Executive Summary

Prepared By

Prof. Panos Michalopoulos

Department of Civil and Mineral Engineering
University of Minnesota

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Submitted to

MINNESOTA DEPARTMENT OF TRANSPORTATION
OFFICE OF RESEARCH ADMINISTRATION
117 UNIVERSITY AVENUE 2nd FLOOR
ST. PAUL, MINNESOTA 55155

INTERSECTION CONTROL
THROUGH VIDEO IMAGE PROCESSING

EXECUTIVE SUMMARY

BACKGROUND

Among the most promising and innovative concepts today for alleviating urban traffic congestion is the use of video imaging for vehicle detection, automatic surveillance, and advanced control strategies. The concept of using video image processing for traffic surveillance and control is not new. Because of its conceptual appeal, research in this area was initiated in the mid 70's in the U.S. and abroad (most notably in Japan, France, and England).

Despite the major worldwide efforts to develop a machine vision system for traffic surveillance and control, a real-time, fieldable device having the capabilities and performance required for practical applications has been elusive. Even though claims to the contrary have surfaced in recent years, concrete functionality performance and reliability verification is still lacking.

Because of this, a system for vehicle detection through video imaging was recently developed at the University of Minnesota. This system is the most mature known video detection device available to date as demonstrated in recent live benchmarks in several U.S. and European cities. The system is being implemented in the I-394 and I-35W freeways in Minneapolis for incident detection, while several other installations out-of-state are either in the implementation or contract negotiation stage.

The success of the Minnesota system (called AUTOSCOPE™) lies in its simplicity, effectiveness, and instant verification. More specifically, in contrast to other more futuristic concepts, the Minnesota system simply emulates loop detectors, a large number of which can easily be placed within the field of the camera's view through interactive graphics. Furthermore, in recent tests its performance matched or exceeded that of loops in vehicle counting, speed measurements, and extraction of certain measures of effectiveness.

Since the preliminary evaluation tests of the AUTOSCOPE™ were very encouraging, the next step was to test the system in the field through installation at an intersection. This has been repeatedly requested by Mn/DOT, the Local Road Research Board (LRRB), and practicing engineers during the numerous demonstrations of the AUTOSCOPE™ System at the Traffic Management Center in Minneapolis and in other states. Together with Mn/DOT, LRRB has supported this project with 50% matching funds. Thus implementation of the AUTOSCOPE™ System at an intersection and direct comparison with loop detectors for testing validation and calibration has been the objective of this project.

To specifically demonstrate the effectiveness of the new technology in this project, AUTOSCOPE™ was installed in the field and replaced loops for controlling the northbound approach of the intersection at State Highway 65 and 53rd Avenue in Columbia Heights, Minnesota.

During the course of this demonstration project, the industry has witnessed the commercial viability of the AUTOSCOPE™ and the deployment of AUTOSCOPE™s at 27 intersections in Oakland County, Michigan, as well as in several other cities, is currently in progress. Furthermore, the project has exposed the new technology to many practicing traffic engineers in a very visible and convincing way and has encouraged its widespread use.

PROJECT SUMMARY

Succinctly stated the objectives of this project were: 1) to field test and calibrate AUTOSCOPE™ at an intersection over a sufficiently long, continuous time to ensure reliability and robustness, 2) to directly compare AUTOSCOPE™ with loop detectors to demonstrate accuracy and performance, and 3) to modify the existing detection algorithms so that it works well with stationary traffic, since initially it was developed by employing cameras in freeways.

The project started on 8/13/90. A steering committee was nominated and the intersection site was selected. Figure 1 shows the layout of the intersection. AUTOSCOPE™, camera, camera housing, VCR, video monitor, and parts for the signal controller interface were procured. The interface between the AUTOSCOPE™ and the signal controller was designed and built. A Result Recorder was also built for automatically monitoring AUTOSCOPE™ performance and comparing it to loop detectors. The Result Recorder is the component of the Automated Evaluation System specifically employed on this project for measuring the performance of two similar detection systems.

Significant delays occurred due to equipment problems, such as: procurement, a defective camera heater, the wrong transceiver (two months), debugging the interface to the controller, camera optics which needed to be replaced, an air conditioner needed for hot weather, and generally adverse weather conditions which effected field installations.

After all equipment was installed and/or fixed, preliminary testing began. The extension detectors in the through lanes were 420 ft.

from the camera. The camera was originally placed on the signal pole at a height of 32 ft., which limited the field of view to only about 300 ft. The AUTOSCOPE™ requires 1 ft. of camera height for every 10 ft. of downlane range to "see" gaps between vehicles in order to achieve acceptable volume accuracies. The initial testing of the AUTOSCOPE™ at a camera height of 32 ft. gave volume accuracies as low as 75% at the point where loops were placed (420 ft. from the camera) during peak traffic flows. A 50 ft. wood pole was installed to improve the performance which gave a final camera height of 42 ft. after installation. Further testing at 42 ft. showed consistent volume accuracies of 92-95%. We also performed further tests of comparing the loops at 420 ft. to AUTOSCOPE™ detectors placed at 350 ft. and found consistent 24-hour volume accuracies of 95-100% under various weather, lighting, and traffic congestion conditions. AUTOSCOPE™ performance was also analyzed by varying the rotational view of the camera about the viewing axis. The best performance was obtained by aligning the horizontal axis of the camera perpendicular to traveled lanes.

Test metrics for the left turn and through movements were defined, discussed, and approved by Mn/DOT. (Test metrics define a standard method of measuring an attribute of the testing process.) Volume and occupancy (later replaced by gaps between successive vehicles) were measured for the through lanes and the left turn. The Result Recorder was modified to enable which detection system provides input to the controller (AUTOSCOPE™ or loop detectors) is used and collect the left turning and through lane test data.

Additional capability of the Result Recorder has been implemented so that it continuously monitors loop and AUTOSCOPE™ performance; and when AUTOSCOPE™ performance falls below specified threshold levels, the input to the controller switches from AUTOSCOPE™ to the loop detectors. Threshold values have been determined jointly by Mn/DOT and ISS.

Algorithm and equipment modifications were developed to improve AUTOSCOPE™ performance under certain conditions (i.e., sudden lighting changes, as at sunrise or sunset and during the night). A new type of presence detector for the left turn has been developed and has significantly improved detection accuracy for stopped vehicles. Some initial problems with the left turning lane detector being stuck on after a vehicle left the detector, have been remedied.

A new "directional" type of detector has also been developed and implemented. It only allows detections from a specific direction (for downlane oriented detectors). This directional capability eliminates false detections that occur at night and also the ones caused by shadows and reflections that enter the detector from the wrong direction. False detections from pedestrians crossing at the stop line can also be detected. This detector can also be used to measure queue lengths.

The delays in installing and testing the AUTOSCOPE™ at the TH-65 and 53rd Avenue test site forced the project to be further delayed because of overlap into a planned construction project at the same site.

Two meetings took place in order to decide if the performance of AUTOSCOPE™ was good enough to allow the AUTOSCOPE™ to monitor the north bound movement during construction. After the first meeting, some members of the team visited the site and were not satisfied with the performance. Several changes/improvements were made as suggested by Mn/DOT, and after the second meeting on-site it was decided that the performance was satisfactory. The AUTOSCOPE™ provided input to the controller during the entire construction period (2.5 months). The AUTOSCOPE™ detectors were used to extend green time of both the through and left turn lanes. The left turn phase was placed in minimum recall. The equipment worked without interruption even during two major thunderstorms. It is important to note that the flexibility of the AUTOSCOPE™ allowed detection zones to be moved three times during the construction process to accommodate various lane diversion configurations. Construction at the project site delayed the testing process by five and a half months from August 1, 1991 to January 15, 1992.

AUTOSCOPE™ was tested under two different site configurations, before and after construction. Before the construction, the northbound approach consisted of two through lanes, one left and one right. After the construction it was changed to three through lanes, two left turn lanes and one right turn lane.

The detector configuration of the final site configuration has three loop detectors 290 ft. from the stop line and 400 ft. from the camera (Figure 2). The loop detectors are used primarily to extend the through movement green phase (gap timing) and secondly to collect 15-minute volume counts for setting system cycle times. To duplicate this functionality, three AUTOSCOPE™ detectors were placed crossline over the loops and OR'd together. To detect loop comparable gaps between platoons, three detectors are placed at the stop line (130 ft. from the camera) to obtain very accurate volume counts (98-99% detection accuracy) for all weather, lighting, and traffic conditions. The two left turn lanes have two, 6 ft. loops in each lane spaced 18 ft. apart for a total coverage 30 ft. Two AUTOSCOPE™ Presence Detectors are placed over the loops to obtain the same amount of spacial coverage. During the course of this project, not a single left turn phase has been missed (not serviced).

During the entire length of the project there was only one system failure due to the extreme heat in the cabinet. This problem was alleviated by installing an air conditioning unit, and is completely eliminated in the AUTOSCOPE™-2003 that has an operating range of -30° F to +165° F.

Overall, we feel that all the objectives of the project were successfully accomplished. Major software changes brought significant improvement in the AUTOSCOPE™ performance and testing, and connecting the AUTOSCOPE™ to the controller increased our confidence in its reliability and robustness. At the same time much experience was gained with the video camera both in terms of its physical placement (viewing angle, rotation, and height) and its internal set up, such as iris, focus, filters, and other camera electronic adjustments such as AGC, gamma, AGC level, etc.

Ray Starr and Dale Burfeind of the Mn/DOT have been closely monitoring the progress of this project and have given us valuable input in evaluating and improving AUTOSCOPE™ operation for signalized intersection control.

A new NEMA specification version of AUTOSCOPE™ has been installed as of April 1, 1992. Image Sensing Systems (ISS) has provided the new version of AUTOSCOPE™ and Econolite will be providing three additional cameras for field testing. The AUTOSCOPE™ will then detect traffic for all four approaches. Mn/DOT has provided pole extensions at each corner of the intersection and power and control lines for each camera to each pole/camera location. These extensions are at no additional cost to this project and will be completed independently of the project.

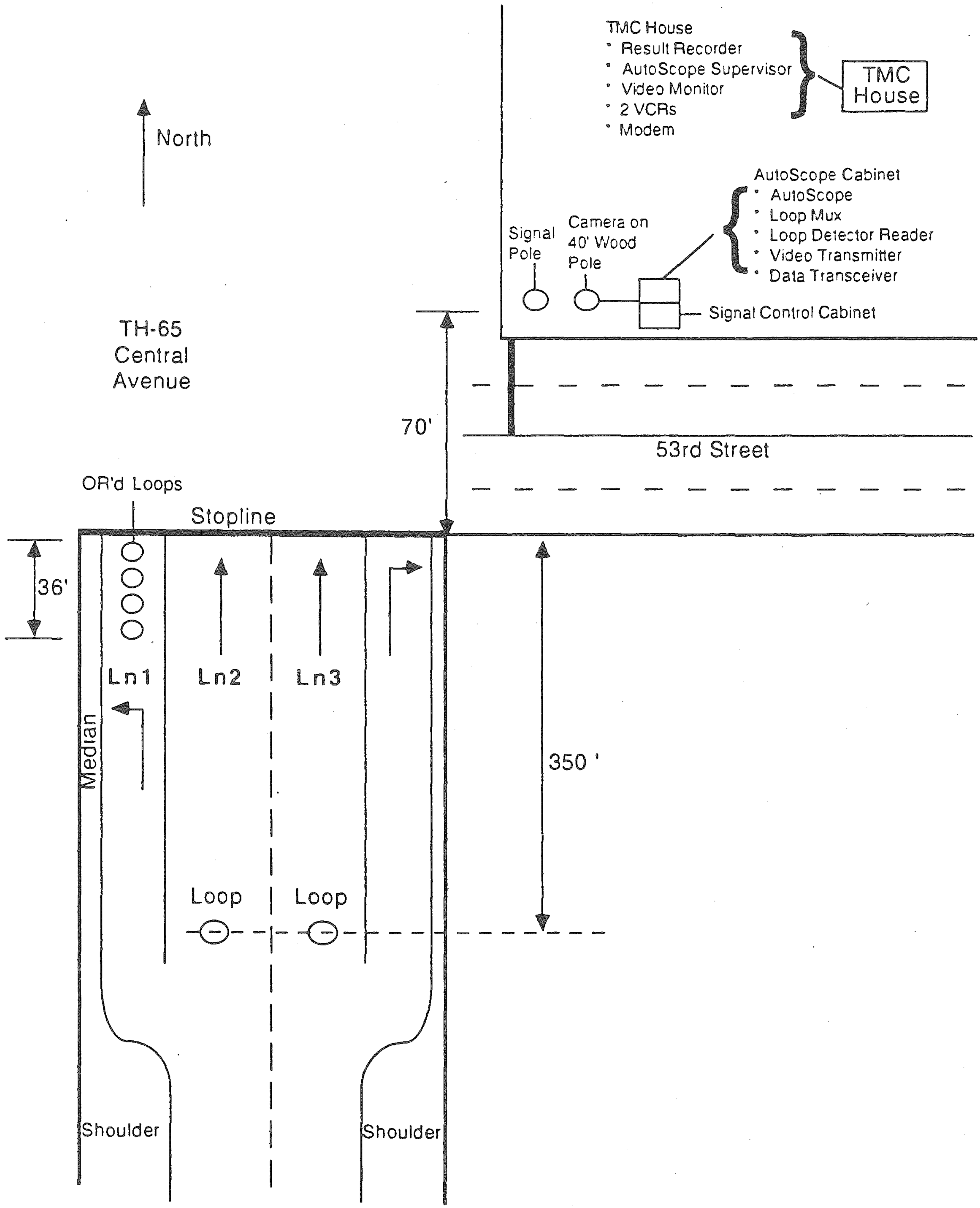
It is recommended that this site remains active as a testing laboratory for the new version of AUTOSCOPE™-2003 and new application development such as: platoon detection, queue length measurements, stops, delays, fuel consumption and, eventually, adaptive control schemes.

Video compression will allow video transmission via phone lines and will make video transfer in a central location cost effective. This will make the job of the traffic engineer more effective and will thus provide the opportunity to find new ways to take advantage of the wealth of information that AUTOSCOPE™ provides.

Finally, it should be pointed out that AUTOSCOPE™ is ready for widespread deployment, and the first such installation is currently in progress at 27 intersections in Oakland County, Michigan.

Intersection Test Site Prior to Construction

(Figure 1)



Intersection Test Site After Construction

(Figure 2)